CLAIMS

What is claimed is:

1. A method comprising:
forming a sacrificial layer on a substrate;
forming a metal layer on the sacrificial layer;
anodizing the metal layer to form a layer of a porous metal oxide; and
forming carbon nanotubes in pores of the porous metal oxide layer.

2. The method of claim 1, further comprising removing excess metal oxide material from the pores of the porous metal oxide layer prior to forming the carbon nanotubes.

3. The method of claim 2, wherein the pores extend through the porous metal oxide layer into the sacrificial layer.

4. The method of claim 1, further comprising depositing a catalyst in the pores of the porous metal oxide layer prior to forming the carbon nanotubes.

5. The method of claim 5, wherein the catalyst comprises iron, nickel, cobalt, rhodium, platinum, or yttrium.

6. The method of claim 1, further comprising separating the porous metal oxide layer and carbon nanotubes from the sacrificial layer and the substrate to form a free-standing composite carbon nanotube (CNT) structure.

7. The method of claim 6, wherein separating the porous metal oxide layer and carbon nanotubes from the sacrificial layer and substrate comprises dissolving the sacrificial layer.

8. The method of claim 7, wherein the sacrificial layer is dissolved in a solution including an acid.

9. The method of claim 8, wherein the acid comprises phosphoric acid, succinic acid, or sulfuric acid.

10. The method of claim 8, wherein the sacrificial layer is dissolved under application of an anodic potential.

11. The method of claim 6, further comprising attaching the composite CNT structure to a component.

12. The method of claim 11, wherein the component comprises a semiconductor wafer, an integrated circuit die, a heat spreader, or a heat sink.

13. The method of claim 11, wherein attaching the composite CNT structure to the component comprises attaching the composite CNT structure to the component using a low melting point metal alloy.

14. The method of claim 13, wherein the low melting point metal alloy comprises a solder.

15. The method of claim 11, wherein attaching the composite CNT structure to the component comprises compressing the composite CNT structure against the component.

16. The method of claim 15, wherein the composite CNT structure is compressed against the component under a pressure in a range up to approximately 10 Kg/cm^2.

17. The method of claim 6, wherein the composite CNT structure has a thickness in a range of approximately 2 μm to 20 μm.

18. The method of claim 1, wherein the carbon nanotubes are formed to a height extending above an upper surface of the porous metal oxide layer.

19. The method of claim 1, wherein the carbon nanotubes are formed by chemical vapor deposition (CVD) or plasma enhanced CVD.

20. The method of claim 1, wherein the metal layer comprises aluminum and the porous metal oxide layer comprises aluminum oxide.

21. The method of claim 1, wherein the sacrificial layer comprises vanadium, titanium, or tungsten.

22. The method of claim 1, wherein the metal layer is anodized under a positive voltage and in the presence of a solution including an acid.

23. The method of claim 22, wherein the acid comprises one of phosphoric acid, succinic acid, sulfuric acid, and oxalic acid.

24. The method of claim 22, wherein the positive voltage comprises a voltage in a range of approximately 1 to 60 volts.

25. A device comprising:
a porous metal oxide layer; and
a number of carbon nanotubes disposed in pores of the porous metal oxide layer.

26. The device of claim 25, wherein the metal oxide layer comprises aluminum oxide.

27. The device of claim 25, wherein at least some of the carbon nanotubes extend above a surface of the porous metal oxide layer.

28. A device comprising:

an integrated circuit die; and

a thermal interface device coupled with a surface of the die, the thermal interface device comprising a layer of a porous metal oxide and a number of carbon nanotubes disposed in pores of the porous metal oxide layer.

29. The device of claim 28, further comprising a heat spreader coupled with the thermal interface device.

30. The device of claim 29, further comprising:

a second thermal interface device coupled with the heat spreader, the second thermal interface device comprising a layer of a porous metal oxide and a number of carbon nanotubes disposed in pores of the porous metal oxide layer; and

a heat sink coupled with the second thermal interface device.

31. A system comprising:
a bus; and
a device coupled with the bus, the device including
an integrated circuit die, and
a thermal interface device coupled with a surface of the die, the thermal interface device comprising a layer of a porous metal oxide and a number of carbon nanotubes disposed in pores of the porous metal oxide layer.

32. The system of claim 31, wherein the device further includes a heat spreader coupled with the thermal interface device.

33. The system of claim 32, wherein the device further includes:
a second thermal interface device coupled with the heat spreader, the second thermal interface device comprising a layer of a porous metal oxide and a number of carbon nanotubes disposed in pores of the porous metal oxide layer; and
a heat sink coupled with the second thermal interface device.

34. The system of claim 31, wherein the device comprises a processing device.

35. The system of claim 34, further comprising a memory coupled with the bus.

36. A method comprising:
forming a sacrificial layer on a substrate;
forming a layer of a porous material on the sacrificial layer; and
forming carbon nanotubes in pores of the layer of porous material.

37. The method of claim 36, further comprising depositing a catalyst in the pores of the layer of porous material prior to forming the carbon nanotubes.

38. The method of claim 36, further comprising dissolving the sacrificial layer to separate the layer of porous material and carbon nanotubes from the sacrificial layer and the substrate.

39. A method comprising:
disposing a substrate in a plating bath including a plating solution, the plating solution including ions of a metal and carbon nanotubes; and
forming a layer of the metal on the substrate, the metal layer including a number of the carbon nanotubes.

40. The method of claim 39, wherein the metal comprises one of tin, indium, copper, nickel, cobalt, iron, cadmium, chromium, ruthenium, rhodium, rhenium, antimony, bismuth, platinum, gold, silver, zinc, palladium, and manganese.

41. The method of claim 39, wherein the carbon nanotubes comprise up to approximately 20 percent by weight of the plating solution.

42. The method of claim 39, wherein the metal layer is formed by electroplating.

43. The method of claim 42, wherein the plating solution further comprises a complexing agent.

44. The method of claim 42, wherein the plating solution further comprises an additive to regulate a property of the metal layer.

45. The method of claim 44, wherein the additive comprises polyethylene glycol or a di-sulfide.

46. The method of claim 42, further comprising depositing a seed layer on the substrate prior to forming the metal layer.

47. The method of claim 39, wherein the metal layer is formed by electroless plating.

48. The method of claim 47, wherein the plating solution further comprises a complexing agent and a reducing agent.

49. The method of claim 48, wherein the reducing agent comprises one of formaldehyde, hypophosphite, dimethyl amine borane, and hydrazine hydrate.

50. The method of claim 47, wherein the plating solution further comprises a substance to adjust a pH of the plating solution.

51. The method of claim 47, wherein the plating solution further comprises an additive to regulate a property of the metal layer.

52. The method of claim 51, wherein the additive comprises one of polyethylene glycol and a di-sulfide.

53. The method of claim 47, further comprising depositing a catalyst on the substrate prior to forming the metal layer.

54. The method of claim 47, further comprising heating the plating solution in the plating bath.

55. The method of claim 39, further comprising applying an electric field across the metal layer to align the carbon nanotubes in the metal layer.

56. The method of claim 55, wherein the carbon nanotubes are aligned substantially perpendicular to a surface of the substrate.

57. The method of claim 39, wherein the substrate comprises a semiconductor wafer, an integrated circuit die, a heat spreader, or a heat sink.

58. The method of claim 39, further comprising separating the metal layer including the carbon nanotubes from the substrate to form a free-standing composite carbon nanotube (CNT) structure.

59. The method of claim 58, further comprising attaching the composite CNT structure to a component.

60. The method of claim 59, wherein the component comprises a semiconductor wafer, an integrated circuit die, a heat spreader, or a heat sink.

61. The method of claim 59, wherein attaching the composite CNT structure to the component comprises:

depositing a layer of a low melting point metal alloy on a surface of the composite CNT structure; and

attaching the composite CNT structure to the component using the layer of low melting point metal alloy.

62. The method of claim 61, wherein the low melting point metal alloy comprises a solder.

63. The method of claim 58, wherein the composite CNT structure has a thickness in a range of approximately 2 μm to 20 μm.

64. A device comprising:

a substrate; and

a layer of metal disposed over a surface of the substrate, the metal layer having a number of carbon nanotubes dispersed therein.

65. The device of claim 64, wherein each of the carbon nanotubes has a primary axis substantially aligned in a direction perpendicular to the surface of the substrate.

66. The device of claim 64, wherein the substrate comprises a semiconductor wafer, an integrated circuit die, a heat spreader, or a heat sink.

67. The device of claim 64, wherein the substrate comprises a sacrificial substrate and the layer of metal having the carbon nanotubes is separable from the sacrificial substrate.

68. The device of claim 64, wherein the metal comprises one of tin, indium, copper, nickel, cobalt, iron, cadmium, chromium, ruthenium, rhodium, rhenium, antimony, bismuth, platinum, gold, silver, zinc, palladium, and manganese.

69. A device comprising:
an integrated circuit die; and
a thermal interface device coupled with a surface of the die, the thermal interface device comprising a metal layer having a number of carbon nanotubes dispersed therein.

70. The device of claim 69, further comprising a heat spreader coupled with the thermal interface device.

71. The device of claim 70, further comprising: a second thermal interface device coupled with the heat spreader, the second thermal interface device comprising a metal layer having a number of carbon nanotubes dispersed therein; and a heat sink coupled with the second thermal interface device.

72. A system comprising: a bus; and a device coupled with the bus, the device including an integrated circuit die, and a thermal interface device coupled with a surface of the die, the thermal interface device comprising a metal layer having a number of carbon nanotubes dispersed therein.

73. The system of claim 72, wherein the device further includes a heat spreader coupled with the thermal interface device.

74. The system of claim 73, wherein the device further includes: a second thermal interface device coupled with the heat spreader, the second thermal interface device comprising a metal layer having a number of carbon nanotubes dispersed therein; and a heat sink coupled with the second thermal interface device.

75. The system of claim 72, wherein the device comprises a processing device.

76. The system of claim 75, further comprising a memory coupled with the bus.